requirement for an illustrated embodiment to the exclusion of embodiments described with reference thereto.

DETAILED DESCRIPTION

[0043] Reference will now be made in detail to representative embodiments illustrated in the accompanying drawings. It should be understood that the following description is not intended to limit the embodiments to one preferred embodiment. To the contrary, it is intended to cover alternatives, modifications, and equivalents as can be included within the spirit and scope of the described embodiments as defined by the appended claims.

[0044] The embodiments described herein are directed to wearable devices that can detect and respond to user inputs. The user inputs may include either or both of voiced (audible) commands or silent (inaudible) gesture commands of a user. As used herein, a "command," whether voiced or a silent gesture, is to be understood as any of: a user instruction to the device to change the device's operation, an input of data or other information to the device by the user, or another user input to affect the state of the wearable device itself or of an associated electronic device. The embodiments described herein may also be used to record audible or inaudible communications other than commands. The wearable device may include a self-mixing interferometry sensor that uses self-mixing interferometry to detect the voiced or silent gesture commands, or other voiced or silent communications.

[0045] In self-mixing interferometry, a beam of light (visible or invisible) is emitted by a light source of the self-mixing interferometry sensor toward an object. Reflections or backscatters of the emitted beam of light from an object may be received in the light source and cause the light source to enter an altered steady state in which the emitted light is different from light emitted without received reflections. As the distance or displacement of the object from the self-mixing interferometry sensor varies, corresponding variations in the altered state of the self-mixing interferometry sensor are induced. These induced alterations produce detectable variations in a signal of the self-mixing interferometry sensor that allow the distance, displacement, motion, velocity, or other parameters of the object to be determined.

[0046] In various embodiments described herein, the wearable device may be worn or attached to a user, such as on the user's head. The user's voiced or silent gesture commands may induce skin deformations, such as skin vibrations. For example, audible speech by the user may induce skin vibrations at one or more locations on the scalp or head of the user. A silent gesture of the user, such as inaudibly forming a word with the jaw and tongue without exhaling, may induce skin deformations at one or more locations on the scalp or head of the user. The skin deformations may be detected by a self-mixing interferometry sensor mounted on a frame of the wearable device.

[0047] Specific embodiments described in further detail below include a microphone equipped earbud, in which the self-mixing interferometry sensor detects the user's speech or voice based on skin vibrations at a location in the user's ear. In a variation, the earbud may not have a conventional microphone. Instead, the self-mixing interferometry sensor may function for detecting sound inputs. In a second embodiment, an over the ear(s) headphone may include one or multiple self-mixing interferometry sensors that may detect the user's voiced commands or silent gestures from skin deformations at locations proximate to the parietal bone, one of the temporal bones, one of the temporomandibular joints, or another location on the user's head. In a third embodiment, an eyeglass frame may include a self-mixing interferometry sensor that may detect skin deformations proximate to the temporal bone. A fourth embodiment relates to a visual display headset, such as may be used by a mixed reality, an augmented reality, or virtual reality (AR/VR) user headset. The AR/VR headset may include multiple self-mixing interferometry sensors that may detect the user's voiced commands or silent gestures from skin deformations at locations proximate to the parietal bone, one of the temporal bones, one of the temporomandibular joints, or another location on the user's head. These embodiments are listed as examples, and are not intended to limit the embodiments of this disclosure.

[0048] Detected skin deformations may be used in various ways. One use is to recognize or identify a command, whether it be input to the wearable device as a voiced command or as a silent gesture command. Skin deformations such as skin vibrations from voiced commands may be correlated with a known voice pattern of the user. This can allow the voiced command to be recognized and accepted by the device even when the voiced command is not accurately detected by a microphone (such as may occur in the presence of background noise).

[0049] Another use is for bioauthentication of received commands. As an example, a self-mixing interferometry sensor may detect skin vibrations when the user is speaking, and so allow the device to accept the command as it is heard by a microphone of the wearable device. If the self-mixing interferometry sensor does not detect skin deformations or skin vibrations above a threshold, the device may ignore an audible input detected by its microphone. In this way, the device can disregard unwanted voiced commands not made by the actual user.

[0050] In still another use, a self-mixing interferometry signal may be used for audio conditioning. For example, a user's speech recorded by a microphone may contain background noise. A self-mixing interferometry signal may allow the device to determine the intended voiced command, and can transmit (such as to another person or device) a reduced noise version of the voiced command.

[0051] These and other embodiments are discussed below with reference to FIGS. **1-11**. However, those skilled in the art will readily appreciate that the detailed description given herein with respect to these figures is for explanatory purposes only and should not be construed as limiting.

[0052] FIG. **1** illustrates a block diagram of a system **100** by which a wearable electronic device may operate to detect user inputs by detecting or measuring skin deflections or deformations at a location on a user's body. The block diagram of the system **100** is representational only, and does not imply any information regarding dimensions or shape of the features shown. Examples of such electronic devices include, but are not limited to, an earbud, a headphone, an eyeglass frame, or a mixed reality, an augmented reality or virtual reality (AR/VR) headset. These exemplary wearable electronic devices will be explained in further detail below in relation to FIGS. **3**A-B. The skin deformation may be caused by voiced or silent commands issued by the user to affect operation of a wearable electronic device.

[0053] The wearable electronic device may include a self-mixing interferometry sensor **102**. The self-mixing